A RATE-DEPENDENT COHESIVE CONTINUUM MODEL FOR THE STUDY OF CRACK DYNAMICS

T. D. Nguyen[a] and **S. Govindjee**[b] and **P. A. Klein**[c] and **H. Gao**[d]

[a]Division of Mechanics and Computation
Department of Mechanical Engineering
Stanford University, CA 94305, USA
thao@stanford.edu

[b]Structural Engineering, Mechanics and Materials
Department of Civil and Environmental Engineering
Berkeley, CA 94720, USA
sanjay@ce.berkeley.edu

[c]Science-Based Materials Modeling Department
Sandia National Laboratories
P.O. Box 0969, Livermore, CA 94551, USA
paklein@sandia.gov

[d]Department of Theory of Mesoscopic Phenomena
Max Planck Institute for Metals Research
Heisenbergstrasse 1, D-70569 Stuttgart, Germany
hjgao@mf.mpg.de

A rate-dependent cohesive continuum model is developed from a proposed microstructure of material particles interacting in a viscous medium. Interactions between material particles are modeled using a cohesive force law while resistance to local microstructural rearrangements that lead to viscoelastic relaxation is represented by a continuum viscosity function. The model exhibits two failure mechanisms, cohesive bond separation and viscous weakening, that cooperate to induce rate dependence in the cohesive strength, fracture energy, and cohesive state wave speed. The model is used to simulate Mode I crack propagation in a large plate in response to stress wave loading. For the chosen material properties, the results display a terminal speed of $v = 0.6c_R$ for the highest loading rate and $v = 0.3c_R$ for lower loading rates. Accumulation of strain energy appears at the crack tip during propagation at both terminal speeds, and sustained branching is developed during propagation at the lower terminal speed. In contrast, simulations using an elastic continuum cohesive model produce a narrower range of terminal speeds. Dynamic instabilities obtained for the lower loading rates in the viscoelastic case do not appear in the elastic case. The conditions at the crack tip associated with the lower terminal speed develop in the viscoelastic simulations after the arrival of reflected stress waves at the propagating crack front. There appears to be a correlation between the terminal crack speed and the cohesive state of the crack tip. Overall, the results strongly support the hypothesis that physical relaxation processes at the crack tip are important in dynamic fracture of nominally brittle materials.